INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION STUDY GROUPS

Document **8D/58-E**
16 April **1998**
Original: English only

United States **of** America

INFORMATION PAPER

CIVIL, COMMERCIAL AND CONSUMER **USE OF** THE **GLOBAL POSITIONING SYSTEM (GPS)**

1 Overview

The Global Navigation Satellite System (GNSS), as exemplified currently by GPS, its augmentations, and also by the Global Navigation Satellite System (GLONASS), is a distribution system that provides position and time information to the (navigating) mobile user to determine the unique address of every point on earth, and to time tag all events. GPS is information technology that uses systems of hardware and software, as well as information (time and ephemeris) transmitted from satellites to provide derived information to the user. This derived information may be combined with communications devices and computers, such as Geographic Information Systems, to perform a variety of tasks or applications. GPS is now a worldwide information utility supporting a wide range ofcivil, scientific and commercial functions, from air traffic control to the Internet. GPS is dual-use and provides highly accurate, secure, rcliable information to U.S. and Allied forces to navigate anywhere in the world.

The GPS is operated by the U. S. Administration, with the first operational satellites launched in 1989. The constellation became operational for civil use in late 1993, with 21 satellites on orbit. Following further satellite launches and an extensive military test program, GPS was declared fully operational in mid- 1995, with **24** satellites on orbit. The U.S. Administration's Federal Radionavigation Plan, updated biennially since *1980*, anticipates replacement of federally operated radionavigation systems with GPS, as GPS services are authorized for navigation use for various modes of civil and military transportation. Termination phase-out of other navigation systems, such as Transit and Omega have occurred. Phase-out of Loran-C is also being considered. **As** indicated in both the U.S. Presidential Decision Directive on GPS and in statutory language added to Title 10 of the United States Code, GPS, in addition to having military uses, also has essential civil, commercial, and scientific uses. Consequently, the U.S. Administration has committed to provide for the sustainment and operation of GPS services for civil, commercial and scientific uses on **a** continuous worldwide basis, free of direct user fees.

2 Trends in GPS Receivers, Applications and Cost

Two trends have emerged in the CPS market. The first is the continuous 30% per year decline in the cost (which is being driven towards zero), power and size of the electronics hardware necessary to decode the space-based informalion. In 1983, the first commercial receivers cost over $1 50,000 and weighed over a hundred pounds. The next year a portable receiver was introduced that weighed

only 40 pounds and cost $40,000. In 1998, a consumer handheld receiver costs $100 and weighs 7 ounces.

The second trend is the increased contribution of embedded software in the end-user application. User demand is driving product evolution with product cycles of 12 - 18 months. GPS information technology products are priced as a percentage of the user's productivity as determined by return on investment that may be determined within 6 - 12 months. The value to the end-user is in the application of the information which is recovered largely in software. GPS hardware is disappearing as it becomes integrated into the silicon structure that encompasses communications and computation. In commercial markets in particular, the increased software content is the fundamental driver for productivity increases and thcrcfore acts to stabilize unit prices. As an example, in 1986, the cost of a control survey point was around $10,000 using traditional optical survey. In 1997, the cost of a control survey point was under $250 using GPS. In the consumer markets, the software is less of a cost factor and there the traditional erosion of hardware prices is reducing the price at retail. Currently, there are approximately 250,000 conimcrcial units/month in production worldwide. By the year 2000, it is anticipated that there will be approximately 2 million additional users a month worldwide. Today, there arc 958 published patents on GPS worldwide. Europe and Japan currently have the largest segment of the GNSS/GPS-based car navigation industry worldwide. RACAL in the United Kingdom, and FUGRO, in Holland, are prcscntly the leading successful commercial models of GNSS/GPS space-based augmentations for commercial applications.

3 GPS Applications Which Utilize C/A Code Tracking

There are millions of GPS receivers already in use which use CIA code tracking. A significant fraction of these utilize differential corrections, obtained from a radio receiver, to achieve accuracies of 1-10 meters.

In addition, GPS receivers have found wide spread application in the timing business, providing highly stable and accurate timing signals for use in digital communications networks cellular phone applications, and power grids. These reccivers must provide continuous, precise inputs to synchronize networks worldwide. Interruptions, no matter how brief, can have significant unintended safety and economic consequences.

4 GPS Applications Which Utilize Semi-Codeless Carrier Phase Tracking

There are a wide variety of both current and future applications which employ a unique GPS technique that utilizes semi-codeless carrier phase tracking of the Y code signals at L1 and L2 to achieve decimeter level positioning accuracies. These techniques are more sensitive than conventional code-phase receivers to interference from sources such as MSS satellite transmitters. Current examples of such applications include the following:

i. Commercial Differential GPS Networks.

These networks employ a number of ground-based receivers which use semi-codeless tracking techniques to determine ionospheric delays based on broad band L1 and L2 transmissions from GPS satellites.

ii. Surveying receivers,

There are a large number of GPS receivers used for geodetic and other long-baseline surveying applications which use semi-codeless tracking techniques to achieve sub-centimeter accuracies. These receivers are susceptible to interference during both acquisition and tracking.

iii. Robotic applications.

GPS receivers are beginning to be employed to precisely control machine positioning in robotic applications where personnel safety is paramount. Surface mining operations will increasingly utilize these GPS receivers to achieve autonomous operation of mining equipment within proscribed areas.

iv. Drcdgiog.

Removal of sand in harbors to enable ships to navigate safely in channels requires accurate positioning of the dredging equipmcnt. In addition, surveys are conducted by both contractors and authorities in two ways: (1) to estimate the amount of material needing to be removed prior to the dredging operation, and (2) to audit the amount of material removed. Semi-codeless GPS receivers are becoming the standard for dredging operations.

v. Precise control **of** agricultural vehicles

Agricultural vehicles need the decimeter positioning accuracy provided by semi-codeless GPS to control the position of plows, as well as seeding, fertilizing, and spreading pesticides.

Anticipated new applications of semi-codeless tracking include the following:

i. Vehicle tracking **and** control.

Reliable sub-meter accuracy is required for tracking and controlling vehicles for collision avoidance in a variety of applications.

ii. Automatic guidance **of** highway vrhicles.

Rcliable, high-integrity decimeter accuracy is essential for intelligent transportation systems of the future that provide automatic guidance of vehicles on highways.

iii. Long-haseline **surveying**.

New methods of achieving centimeter accuracy of surveys over baselines of several hundred kilometers require the use of semi-codeless GPS receivers.

There are many other applications that are not mentioned here, all of which depend on the semi-codeless techniques to achieve rcliable operation at decimeter accuracies.

5 Compendium **of** Rcprescntative Applications

The following list of current and prospective civil, commercial and consumer applications of GPS is included in a table format that is divided into three columns: Applications, Receiver Type, and Descriptive Example.

The Application column includes a representative list ofcivil, commercial and consumer applications of GPS in:

aviation

communications

environmental protection

agriculture and forestry

public and other ground transportation

health care

- law enforcement and safety

maritime and waterways

mining and construction

recreation, arts and entertainment

infrastructure development and management,

weather forecasting, and other public services.

The Receiver Type column identifies the type of receiver in use for each application using a corresponding number code, 1-10, from the following list:

1 - three channel C/A code GPS receivers

2 - six channel C/A code GPS receivers

3 - eight channel C/A code GPS receivers

4 - eight-lo-twelve channel C/A code GPS receivers

5 - nine channel C/A and P code precision GPS receivers

6 - dual frequency survey GPS receivers

7 - integrated GPS boards or clocks

8 - flight-certified nine-to-twelve channel C/A code GPS receivers

9 - fully-integrated GPS landing systems for small airports

10 - differential GPS marine beacon receivers

The **Descriptive Example** column offers a brief specific example of each application of GPS technology.

APPLICATION: PUBLIC SAFETY	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
Rapid emergency response	3	Emergency Medical Systems (EMS) and fire departments are using rapid-report GPS for automatically dispatching the closest vehicles to emergency locations, eliminating the logistics of limiting a vehicle to a particular zone, thereby reducing response times and saving lives.
Emergency phone call handset location	7	CPS clocks are included in cellular phones for Emergency phone systems to provide the precise timing synchronization between location receivers to pinpoint an emergency caller's handset. This is in support of the FCC E91 { mandate that all cellular phones be location tagged to within 125 meters.
Natural disaster damage assessment	4	Tn the first hours and days after a disaster, it is necessary to make an accurate picture of the damage. GPS data collection greatly reduces the time to gather the information and greatly increases the accuracy of the data in the aftermath of disasters, notably following Hurricane Andrew in Florida, the Oakland Hills fire and the Fountain fire in the Sierra Nevada Mountains. California's Governor's Office of Emergency Services also used GPS after the Northridge earthquake to provide damage assessment. Because the earthquakes destroy recognizable landmarks, precise location information is critical to correct damage assessment.
Volcanic eruption monitoring and prediction	6	In Ttaly and Hawai'i, active volcanoes are monitored using GPS. Deformalion of the cone indicates rising magma and imminent emption.
Drowning search and rescue	2	Rescue personnel save critical time using GPS to help track search patterns to find drowning victims lost in rivers, lakes and oceans around the world.

Lost vchicle search and rescue	4	Developers combine positioning data with virtual reality software to build three-dimensional models of search areas to assist rescue personnel in finding lost vehicles and aircraft.
Earthquake monitoring **and** prediction	*6*	All over the world, high-accuracy GPS surveying receivers are bcing used to monitor the earth's crustal movement with an eye towards better understanding of the causes of earthquakes. In Japan, where earthquakes have caused loss of life and millions in damage, a network of hundreds of GPS stations is monitoring shifts of a few millimeters in fault lines. In the US, GPS systems also gather data for geology research projects related to land mass movement.
Monitoring crustal deformation related **to** earthquakes	5	Precision GPS is also used to measure submillimeter fault creep on California's San Andreas Fault.
Mapping wilderness rails to save lives	5	GPS is used for mapping wilderness and park trails, resulting in better information for locating lost, wounded or trapped persons. Another specific **use** was made by the local fire department at Northern California's China Camp State Park to devise the best way to get firefighting equipment to an emergency scene.
Tracking glaciers, ice **lows** and iccbcrgs	3	Tracking glaciers, ice flows and icebergs with GPS prevent damage and loss of life, and have applications wherever humans travel or live in Arctic regions. Notably in Iceland, the Nordic Volcanological Institute, along with other environmental organizations, is using GPS to track a recent glacier meltdown caused by a volcanic eruption beneath the glacier's ice sheet. The data collected is helping to predict the movement of the ice and flood waters. By allowing effective safety measures *to* be put in place, planning with this Information will save lives in the future.

GPS provides the critical 'oundation for enhanced :mergency response	4	Residents throughout the world are enjoying the benefits of emergency response databases enhanced by using GPS, which provides a cost-effective way to acquire current road network information for emergency response applications.
Flood management	3	**A** major benefit from the development of **GPS** is to prevent ecological disaster. Protecting the environment remains an important function of GPS around the world. Notably on a project impacting Argentina, Paraguay and Bolivia, natural canals are detected and accurately mapped using GPS, and precise height of new channels are designed to facilitate flow for the Pilcomayo River, which **fills** with sediment. This will keep sediment moving through Patino Estuary using river canals to restore the Pilcomayo's flow.
Bomb-sniffing **GPS**		GPS has been combined with magnetometers and other sensors by the U.S. Naval Research Laboratory to make a sensor array platform guided and navigated by GPS technology for more effective detection of unexploded ordnance, invaluable in saving lives throughout the world.
Monitoring shifting wildings after disasters	4. 5	A variety of CPS survey systems measure the shifting of buildings after earthquakes, bombings and other disasters to ensure their safety. Notably, the Oklahoma City Survey Division and their contractors used a variety of GPS survey systems to measure the shifting of buildings surrounding the Alfred P. Murrah Federal Building after its bombing.

APPLICATION: AVIATION	RECEIVER	DESCRIPTIVE EXAMPLE
. GPS to maximize aircraft fuel savings and to enhance operational safety Less expensive and more accurate avionics	8	Regional airlines, the fastest growing segment of the avionics industry, are using GPS to provide precision navigation for point-to-point flights, which saves time and fuel and also increases overall safety. Also, GPS equipment has replaced less precise and less safe navigation procedures.
. Commuter airline navigation	8	GPS is used for enroute navigation through precision approach for landing.
. Local, national and international enroute navigation for commercial air transport	8	Airlines all over the world are retrofitting aircraft with GPS-based navigation systems.
Arctic navigation	4	GPS is used for navigation near the magnetic pole in the Arctic, because compasses cannot be used, as well as GPS providing a navigation system that is not dependent on land-based radio systems.
· Improved aircraft separation	8	GPS is useful for maintaining standards for more efficient air traffic separation and throughput.
. Airport surface traffic management	8	GPS is useful for tracking and managing aircraft tax and terminal traffic operations.
Precision All Weather Approaches (LAAS)	8	Aircraft use GPS for safe precision approaches in any type of weather.
Seamless (global) air space management	8	GPS provides inflight monitoring of position and location.
Enhanced direct routing for aircraft fuel savings	8	Operational costs of airline fleets are reduced with more efficient real-time flight planning.

. Surveying remote airports	5	The Ministry of Transportation Ontario, Canada, uses the data collected by two precision **GPS** receivers to obtain accurate **NAD83** coordinate data to improve navigation for pilots at six remote airports located in Ontario's far north. These coordinates are for the centerline thresholds of each of the six airport runways, giving better access to Indian Reserves in the area.
. Affordable, accurate landing systems **for** developing nations and small and/or remote airports	9	In China, GPS is playing an important role in the development of the country's air travel infrastructure. In Juneau, Alaska, a differential GPS landing system has increased landing safety. Known for its difficult approaches, this airport is surrounded by a rugged mountain range called the Chillcat Mountains. Formerly known as one of the most dangerous places to land, GPS transformed the landing field so it is no longer hazardous.
Pilot instruction and education	2	GPS tracks actual flights and allows pilots to analyze their own performance. For example, Embry Riddle University, one of the world's leading aviation training schools, uses GPS to provide guidance for flight training operations.
Search, location and rescue **of** downed aircraft and pilots	1	During the production of a television show called 'Braving Alaska," a small biplane went down just a few miles north of Vancouver, Canada. Rescue pilots would not have been able to find the crash in he dense forest growth without the GPS coordinates supplied by rescue workers on the ground. GPS was also instrumental in rescuing Captain Scott O'Grady, he pilot downed in Bosnia.
Flight procedure and Navigational aid testing		n addition to providing the foundation for the :lobe's next-generation, GPS is also used to *test* the iccuracy of current navaids. GPS is used by the FAA in its flight inspection fleet.

APPLICATION: COMMUNICATIONS	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
. Precise timing for network security protocol!	*3*	GPS timing provides critical timing data for secure Internet messages and setting times on computer networks.
. Cellular phone synchronization	*7*	Wide-area synchronization of code domain multiple access (CDMA) cellular phone networks are used worldwide.
Electrical power control	*2*	Synchronization of power plant generators provide electrical phase matching and fault detection throughout U.S. power grids.
Validation of information transmission	*2. 3*	A large, international investment bank uses GPS to time trades on its worldwide network between New York and London. The GPS information ensures the price of a trade by adding a precision time stamp to trade information.
Network managcmcnt and control	*2*	GPS is used to time and manage paging networks worldwide. Its paging network towers are equipped with GPS sensors to time transfer of messages and to get networks up and running quickly after failures.
Timing of national broadcast programs with local advertising	*2*	Television companies utilize a GPS-based system to coordinate national broadcast programs, such as sports events or live news programs, with local commercials during programming breaks.
Cellular phone position determination	2, 7	Mobile position determination is used for rapid linking for the Personal Communication Systems (PCS).
Wireless comniunication n developing countries	*7*	Precise timing and synchronization for wireless local loop systems using GPS is a major technology for developing infrastructure in underdeveloped countries.

APPLICATION: ENVIRONMENTAL PROTECTION	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
. Overviews of cnvironmcntal phenomena	4	Comprchensive views of deforestation, as well as environmental phenomena in lake, rivers and estuaries, are analyzed and comprehended through overviews of a variety of spatial features.
. River management to avert natural disasters	6	In Paraguay, GPS is used to detect natural canals and precisely determine the height of new channels to facilitate correct sediment deposit, and **thereby** controlling water flow and preventing floods.
. Ground mapping of ecosystems	4	GPS is used to map all manner of ecosystems, from eel grasses in the Puget Sound to coastlines in Louisiana. This information is used to protect wildlife and vegetation.
GPS to administer environmental and territorial resources	6	With GPS at its core, Italian companies developed a system of computers and imaging equipment to gather information about road networks **with** inventories of features and attributes required for the administration and maintenance of the network.
. Archaeological preservation	4	In Westcm Greece, archaeologists are using GPS to map Grecian architecture that span more than 3,000 years of history. These architectural structures and features of the Peloponnesian landscape (known as the Morea in the Middle Ages) are being discovered, mapped, and studied before they are destroyed by man and nature.
. Monitoring crustal deformation rclatcd to earthquakes	5	Precision GPS is used to measure fault creep at the submillimeter level in Japan, Chile, the U.S. and other worldwide locations.
Preservation of indigenous civilizations	4	In the Amazon Basin of Venezuela, anthropologists use GPS for aircraft navigation and mapping the location of villages, rivers and other important sites.

. **Monitoring health of the food chain**	2	If microscopic plankton die, marine life higher on the food chain also perish. GPS is used to facilitate the collection of samples to study the effects of ultraviolet radiation on bacterioplankton.
· **Preventing ground water pollution**	2	GPS equipment is used to map the migration of toxic plumes in ground water. For example, in Texas, the National Resource Conservation Commission is mapping wellheads for an exact location inventory of wells and potential contamination sources.
. **Air pollution measurement**	4, 7	GPS receivers are coupled with gas sensors to map positions of gas concentrations for scientists to correlate satellite data with ground-based research.
Prcscrving national park lands	4	Accurate GPS survey data is used to determine the location **of** unauthorized trails, assess damage to vegetation and thereby carry out restoration projects.
. **Hazardous waste site investigation**	5	With the protective gear necessary at a hazardous waste site, it is difficult to use conventional surveying techniques. GPS is used to perform real-time layout using digital terrain modeling of proposed grading of rubble material at sites heavily contaminated with asbestos, lead dust, PCBs and other hazardous materials.
Monitoring of natural gas and oil pipelines	2	**A** German firm uses **GPS** to develop intelligent pipe corrosion detection tools, affectionately known as 'pigs.' GPS provides extremely precise information on defect locations so that operators can quickly repair dangerous flaws and problems.
Stopping desertification	4	Resource managers use **GPS** to augment other information gathering to develop management plans to combat desertification of the region, for example **in** the Sudan.

. Protecting endangered species	2, 4	GPS is used to map endangered species habitats around the world and track migratory patterns. For example, Venezuela's Harpy Eagle's habitat is mapped with GPS to create buffer zones around nests to stabilize its declining population
. Inventorying interstate pipclines	4	During corrosion survey inspections, oil companies use GPS to map pipelines and produce data for use in third-party excavator damage protection, risk management, spill protection response, and enhanced pipeline integrity.
. Oil spill tracking and cleanup	10	GPS on buoys track the movement of oil spills and monitors how fast a spill is spreading, even in darkness and had weather. This information helps to get emergency crews to the spill at the right time.
. Protection of water resources	4	Scientists at the Florida Department of Environmental Protection are using GPS to prevent pollution of Floridan wells, the source of more than 90 percent of the area's drinking water supply by mapping possible contamination sources for these wells.
EPA uses GPS to certify compliance	4	Scientists at the University of Texas at Austin, Bureau of Economic Geology, working for the Environmental Protection Agency (EPA), Region 6, use GPS to locate regulated facilities in Texas and New Mexico, along the Mexican border. Using GPS data collected in the field, scientists can download positional information that includes toxic release inventory and industrial waste producers and transporters, Superfund sites/landfills, and underground storage tanks.
GPS guides unmanned rcmediation efforts	5	CPS is being used by engineers to develop, in partnership with the Department of Energy, a 40 ton, prototypical, track-mounted, unmanned ground vehicle for hazardous environmental remediation.

Archaeology and cultural preservation	2	Students are using GPS to interact with Geographic Information System (GIS) databases of the San Bernardino National Forest. The units allow students to infer possible Serrano Indian sites, using contour, hydrology, soils and vegetation coverage.
. Mapping of sub-surface contamination	4	GPS is used to map pollutants in Arctic ice. Results showed that even in the remote Arctic, industrial chemicals have become integrated into **the** ecosystem.
. Precise location of stored hazardous materials	4	In Albuquerque, NM, **GPS** is used in efforts to stabilize nuclear wastes from the Rocky Flats nuclear weapons plant, which operated from 1950 to 1980. Surveyors and engineers **used** GPS to precisely map the locations of hazardous waste sites.

APPLICATION: FORESTRY AND AGRICULTURE	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
. Instant mapping of fire perimeters	4	GPS mapping receivers are used in helicopters to fly the perimeter of fires for dynamic mapping, which allows more efficient use of firefighting resources, as well as saving forests and homes.
Precise plowing, planting, fertilizing and other farm uses	2.4	GPS data is collected in the field to control weeds and disease, as well as mapping field boundaries, roads and irrigation systems. Variable rate application of fertilizer in apple orchards and vineyards can be done in combination with GPS mapping. Minimizing application of fertilizer prevents ground water runoff into streams. GPS yield monitors number 8,000 in the field in the U.S. alone with their use doubling every year.
. Precision crop dusting by aircraft	4	In Chile, crop dusters can spray pesticides on banana plantations without using row-end human flaggers to guide pilots. Instead, GPS guides the pilot showing when the end of a field or area has been reached. Workers avoid exposure to highly toxic agricultural chemicals. Helicopters use GPS to help pilots control aerial application of pesticides and other chemicals on crops. GPS helps control spray drift of chemicals.
. Unmanned (robotic) harvesting and plowing	1	At Stanford University, graduate students are working on an experimental autopiloted tractor that could work in any weather, 24-hours a day.
. GPS in agricultural rrmote sensing	1	GPS provides the necessary georeferencing for nformation from satellites and aircraft remotely scanning the earth to monitor crops, map soils and predict crop yields.

GPS to evaluate aerial video missions	4	Remote sensing aircraft **are** made more precise for spectral analysis when combined with **GPS** in **forest** monitoring, vegetation community interpretation, rangeland research and soils assessments by the **USDA** Forest Service.
Uncartbing thc hidden cffeets of logging machines	**4**	Efficient land managcment, particularly imperative in a small country like New Zealand, incorporates **GPS** equipment to map the extent and seventy of logging machine travel to identify harmful soil compaction.
Mapping fire roads for more effective fire fighting	**4**	Professional foresters at use GPS to assist park service officials in mapping **fire** roads, buildings, and other structures in an cffort to make fighting fires easier and more effective.
. **Water resource protection from agricultural chemicals**	***4***	Controlled application of chemicals, even in darkness, prevents ground water runoff into the water supply.
GPS on combines measure grain yields	4	GPS equipment is installed on combines to measure location in developing maps of grain yields for farmers.
. **GPS aids vineyard and winery managcment**	**4**	GPS is used for precision agriculture applications for more than 320 acres of zinfandel grapes. In addition **to**
Pest and weed control	2, 4	Representatives of The Integrated Pest Control Branch of the California Department of Food and Agriculture use GPS to assist in the effective and efficient control of pests and noxious weeds in agricultural areas **throughout** the state of California,

APPLICATION: PUBLIC AND OTHER GROUND TRANSPORTATION	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
Truck fleet on-the-road nanagement	1	More than 225,000 trucks worldwide are scheduled, tracked and monitored using satellite-based communications and GPS. These systems improve service and fleet communications. **A** Dutch trucking company uses GPS-based automatic vehicle location system to schedule and track trucks delivering perishable produce to market before it spoils.
Monitoring status *of* ıridges	6	High accuracy GPS survey receivers are installed at critical locations on bridges to measure deflection an deformation. This data is used to engineer reinforcements to ensure bridge integrity and safety.
Positioning for railroads ınd collision avoidance	2	The Spanish FGC uses GPS to economically report train positions to its control and traffic center in Catalonia. GPS devices are used for position reporting in their locomotives internationally. Positive Train Control is another application being investigated, where high accuracy is needed to avoid collisions, since tracks are often only a few meters apart.
Cargo fleet tracking and rcurity	2	Truck fleets in the U.S., Brazil and other South American countries use GPS to achieve efficient routing and scheduling. In addition, trucks carrying dangerous or high-value cargo can be tracked to protect against hijacking.
"You Are Here" napping displays	1	Communication mnnagcment is enhanced by GPS for fleet transportation and event reporting with **users** ranging from Portland and Chicago 911 to San Francisco paramedics, Boston EMS, Houston Fire Dept., Broadway Cab in Portland, security applications in lreland and Northern Ireland, and armored car tracking in Moscow.

. Improved taxi and other public transportation services	3	In Singapore, a taxi service has added a new twist to hailing a cab. Callers use an automated system that automatically sends a message to the closest cab. GPS is used to constantly update the system on cab location so it can find the nearest vehicle to the caller. GPS-hascd Automatic Vehicle Location (AVL) systems also improve scheduling and management of bus fleets, subways, monorails and other public transportation systems.
. Intelligent Vehicle Highway System (IVHS)	3	In Albuquerque, NM, the Transit Department uses GPS for integrated Intelligent Transportation System (ITS) architecture that includes GPS AVL systems, wireline and wireless communications and GIS data. This intelligent transportation architecture provides tracking, monitoring and scheduling systems for fixed route buses, vans, and paratransit vehicles in the city. The next step using GPS for traffic management and flows would be in autopilots for vehicles.
Students use CPS on real-world projects	2	A classroom in downtown Detroit used GPS to map bus routes for more efficient student transportation at the Aviano Air Force Base in northern Italy.
Public transit control	2	In cities such as Baltimore, Atlanta, Denver and Milwaukee, the transit authorities use GPS-based technology to allow dispatchers to visually locate and track each vehicle on a map display for route and schedule adherence.
Public transit voice annunciators	3	GPS is used to trigger automatic voice annunciators on buses to ensure compliance with the American Disabilities Act. GPS location triggers a voice recording to announce bus stops.
Bus transportation efficiency using CPS	2	GPS as the key positioning component for automatic vehicle location systems provides low-cost, reliable vehicle position data referenced to a common coordinate system.

CPS reference for ransportation systems **on** he Internet	5	Users of the World Wide Web can download reference information from the Texas Department of Transportation, which maintains a Regional Reference Point System using GPS receivers as the backbone of the system. It provides precise regional reference points throughout a network of nine stations.
Commercial vehicle racking and :ommunications	3	Vehicle fleet operations use GPS-based automatic vehicle systems to track everything from taxis to tow trucks. Delivery services streamline their response time for customers by knowing where every delivery vehicle is at any time. **As** another example, in Australia, GPS units include an emergency response system that protects cab drivers. Pushing the button sends a location stamped message to dispatchers who can contact police with the exact location of the incident.
Transportation system :fficiency	5	Throughout the state, the California Department of Transportation allocates GPS survey receivers to every district for their use, as well as for the National Geodetic Survey, for better definition in Geographic Information System (GIS) mapping.
In-vehicle navigation and clcmatics	I	GPS-based systems with computer technology provide drivers with a cornucopia of traffic, weather and location information. In Japan, drivers use these systems to stay away from traffic jams and avoid construction delays, for example.
Highway facility and naintenance	2, 3	The use of snow removal equipment is made more cfficient and effective with GPS.
Vchicle control systems		**An** automotive company uses GPS *to* track driving patterns and vehicle emissions performance as a function of altitude.

Accident location studies	3	In Wake County, NC, police are using a **pen-based** computer system to collect data on accidents. **The** system includes access to GPS data provided by **GPS** units in police cruisers. Using GPS, officers can accurately record the date, time and location of an accident and link that information to other records. Analysis of GPS mapped data is used to study high accident areas and develop engineered solutions to improve highway safety.
Conducting highway surveys	5	The New York State Department of Transportation has a highway-planning model for GPS precise control surveys that has never failed after **250** projects.
In-vehicle wireless voice systems	3	The Quecnsland, Australia train system uses an automated GPS-based system to announce stops to onboard passengers and provide train locations to waiting passengers. Automobile voice direction is another technology made possible by GPS.
Improving fleet operations and security	7	The integration of GPS with cellular technology **is** useful to deter vehicle theft and vandalism by detecting vehicle movement during off-hours, reporting its location to an operations center and triggering preventive measures such as shutting down ignition or activating a burglar alarm. Its route management capabilities can help improve efficiency, verify delivery or ensure route compliance. **It** can also monitor vchicle use, such as the number of miles driven, and remind managers of the need for routine naintenance.
Highway ronstrurtion	5	Survey data is used to design construction projects. Then, location information is fed into machinery to provide precision guidance during construction.

APPLICATION: HEALTH CARE	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
Insect infestation napping	4	The University of New Mexico mapped insect infestations in 11 Western states. The data yielded patterns that enabled disruption of insect life cycle, saving crops and reducing the use of insecticides.
Epidemiological mapping	A	In sub-Saharan Africa, malaria causes the deaths of more than **1.5** million children annually. In a **1995** study, the CDC in Kenya used GPS to create a GIS of households, mosquito breeding sites, local health clinics, and permanent and seasonal rivers. Entomology and childhood mortality databases **are** linked to the GIS so that researchers can study the relationships between disease data and geographic factors.
Personal navigation for blind persons	4	**A** system that uses synthetic speech connected to GPS location data is being developed at the University of California at Santa Barbara. This stereo-system will actually 'tell' sight impaired individuals where they are and will use volume to indicate proximity to a landmark.
Transportation of physically handicapped individuals	3	A San Francisco-based company uses a GPS-based **AVL** system to schedule and track its fleet of vans.
Tracking of Alzheimer and other patients	3	**A** Florida-based company has developed a GPS personal tracking system that tracks the whereabouts of the individuals wearing the device. This system is being used in a multitude of applications, including the tracking of Alzheimer's patients.

APPLICATION: LAW ENFORCEMENT AND SAFETY	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
Dispatch of ambulan police and fire dcpartment personnel and equipm in world-wide use	3	All over the world, CPS-based Automatic Vehicle Location (AVL) systems are becoming nearly as common as radio dispatch to improve the responsiveness and efficiency of emergency services. These systems save lives by shaving minutes off the time between a call and the arrival of an emergency team at an accident or incident site.
100% accuracy in search and rescue operations	1	Nelson, Australia police reported 100% accuracy on tracking clues to permit concentration on the rescue search itself.
Tracking and recover stolen vehicles	7	One company uses CPS for its stolen vehicle recovery service which has a 95 percent recovery rate for stolen vehicles. Companies in Italy, South Africa and Argentina use GPS precise positioning technology to help police find stolen and hijacked cars and vehicles.
Apprehension of seria rapist using CPS	4	In Chaumberg, Illinois, police used GPS to track the attacks of a serial rapist and develop a precise pattern, leading to his apprehension by predicting the time and location of his next attack.
Locating disabled vehicles for road servic	7	CPS-tagged cellular phone calls help towing services find disabled vehicles.
Using GPS with rescu jogs	2	The California Rescue Dog Association used GPS to determine exactly where dogs have searched to identify areas that were not sufficiently covered. The Contra Costa County Search and Rescue Team uses to search give workers a better picture of where to concentrate rescue efforts, as well as to help keep track of where dogs have searched.

Enhanced Ernergcncy elephone services	4	GPS-linked technology provides information on caller locations by querying a telephone company database of addresses matched to phone numbers. In Oregon, GPS was used to build highly accurate databases of mapped addresses that provide the foundation of Oregon's E911 system.
Rescue in foggy, nclcment weather	2	Because an ambulance could not race to the scene without threatening to cause another accident, a GPS-equipped helicopter followed GPS latitude and longitude coordinates from the Highway Patrol on the scene. Funds for the purchase of the Highway Patrol's GPS receivers came from the passage of a state helmet law.
Locating contraband or llegal substances	6	Law enforcement agencies in South America use GPS to track and locate narcotics operations. The Oklahoma Bureau of Narcotics uses GPS to mark the locations of marijuana fields from the air. Then agents can find the locations on the ground using the GPS coordinates.
Forest fire tracking and :ontainment	7	Using GPS and weather service maps, Oregon fire fighting aircraft are able to investigate lightning strikes to see if a forest tire has been started. If a tire *is* found, the pilot records the location and then brings the data back so that fire containment operations can go right to the fire location.
Parolee monitoring and racking	3	In Florida, law enforcement agencies are using a GPS-based system worn by parolees to track them. The system ensures that parolees do not violate their parole, and keeps constant track of their location in real-time.
Flood management	6	In Paraguay, GPS is bcing used to survey and map river canals for the Pilcomayo River, which is currently filled with sediment. The goal of the project is to keep sediment moving through Patino Estuary using river canals to restore the Pilcomayo's flow.

APPLICATION: MARITIME AND WATERWAYS	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
Emergency distress signals on the high seas	1	GPS and satellite communications systems are now required by the International Maritime Organization (IMO). 40,000 ships will *soon* be required to carry a GPS-based system that can send out emergency distress signals that include location and time GPS data.
Arctic ice breaking	2	A Canadian geophysical survey company, has developed a shipping channel mapping system using GPS. The system measures ice thickness to determine the best path for breaking ice in Northwest Passage shipping lanes.
Mapping underwater obstacles during hydrographic surveys	5	The HMNZ Ship Monowai used GPS to re-survey parts of the New Zealand coast to update navigational charts initially produced by the Royal Navy in the 19th century. GPS coastal and harbor surveys provided better than three-meter accuracies, and deep-water surveys were accurate to approximately 15 meters.
All-weather harbor navigation approach	10	The U.S. Coast Guard and countries all over the world use GPS to provide critical navigation data for coastline and harbor navigation.
Precise navigation of inland waterways and collision prevention on the high seas	2, 4, 5	GPS is used by ship captains to accurately navigate through channels, frequently through inclement weather. The GPS units also helps prevent collisions on the high seas.
Positioning of buoys and navaids	5	In the U.S., the Coast Guard uses GPS to position navaids and buoys on the coast and inland waterways. To date, 14 countries use GPS equipment for use in their long range beacon systems
Giving the edge to racing sailboats	2	Because some locations are out of reception for Loran signals, GPS gave the racer's edge to the yawl Avatar, as well as other racing yawls.

Dredging of harbors and waterways	4, 5	GPS is being used in a dredging operation on the Panama Canal and at hundreds of other locations around the world.
Location of commercial fishing traps and nets	2	A northeastern American oyster farming operation uses GPS to map and navigate to oyster beds. Commercial fishing operations also use GPS to mark the location of productive fishing sites.
Ship trials and testing	4	GPS plays a critical role in the trials of newly constructed ships.
Vessel traffic services	2	One oil company uses a differential GPS vessel tracking system to replace positioning vessels visually before dropping anchor for fueling operations.
Harbor facility management	6	In Dubai (United Arab Emirates), GPS-based systems are used to schedule delivery and loading of containers at one of the busiest ports in the world. In Los Angeles, a fleet of ocean liners is managing a brand new facility using a high-tech system that includes GPS-based container tracking.
Locations of shipping containers and auto-piloted barges	1	In Asia, CPS-based systems keep track of containers and auto-piloted barges to ensure cargo safety.
Observing tides and currents	6	GPS technology is used to study tidal motion of large bodies of water. GPS can track tide height to an accuracy of two centimeters. This information is used to develop highly accurate tide charts for better design and maintenance, as well as safer management, of ports and harbors.

APPLICATION: MINING AND CONSTRUCTION	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
Precision location for mine surveying	1	In Indonesia, GPS is used for better scheduling and achieving better throughput at the terminal of unmanned coal barges from several remote areas. Scheduling is complicated by a variety of factors, such as different barge sizes, unloading into an area for the correct grade of coal, various barge journey times, varying loading times at the mines and terminal, railroad scheduling at the terminal, and so on.
· Bridge and other marine construction operations . Bridge and other marine construction operations	4	In Korea, GPS-based technology was used to install with ccnlimetcr precision the pre-built center-arched 150-meter span of the Seo-Kang Grand Bridge. An earlier span, incorrectly positioned, had failed and fallen into the river.
· Cost-cutting and increased productivity in open cut mines . Cost-cutting and increased productivity in open cui mines	5	Real-time surveys in Queensland, Australia are used for local planning and control, topographic and detail work in open cut mines.
. Development of master-planned communities		Construction of a planned community in northern California was aided at the front-end by developers using state-of-the art GPS technology, which is particularly as local agencies have smaller budgets and fewer resources.
· GPS to position piling rigs		GPS receivers provide differential, real-time kinematic (RTK) positioning for surveyors *to* assist rig drivers in accurately positioning rigs over pile.
. CPS speeds construction of new ports in fog and darkness		The positioning of 1200 piles for the pier of a new Northern Brazilian port was successfully accomplished, including in conditions of fog and darkness, using GPS.
Perfectly vertical construction		Auckland, New Zealand's Sky Tower, the seventh-tallest tower in the world, remained perfectly vertical during construction using the precise positioning of GPS.

APPLICATION: RECREATION, ARTS AND ENTERTAINMENT	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
. **Recreational boating and sport fishing**	2, 4	Allows boaters to know their precise position to avoid running aground, making sailing and boating safer — even for novices. Allows mariners to navigate 24 hours a day in any kind of weather, including heavy fog.
. **GPS transfers reality into virtual reality for racers**	4	A San Francisco audience flew through an accurate virtual depiction of the City's terrain, including a trip across the Golden Gate Bridge in a virtual world created from GPS positioning data.
. **Tracking and monitoring of golfers and golf carts**	7	Several companies have developed systems that tracks golf carts and players, allowing golf courses to tun more efficiently through better scheduling of tee off times and better monitoring of player locations on the course. GPS also informs golfers of the accurate distance to the cup, enabling them to better choose the correct club.
. **Special effects and sound timing for film and video production**	1	Using GPS, a special effects filming company has created a whole new industry in Hollywood. During the product of the feature film "Daylight," GPS timing was used to mark actual footage so that special effects could be added at the right place in the film. Hand-held GPS receivers were also used to time sunrise and sunset for the filming of "Forest Gump."
. **Auto and bike racing course planning**	1	GPS is used to give some competitors the edge with pre-race planning by marking out the entire racing course.
. **Navigation and safety for hikers. bikers and trckers**	1	One expedition leader uses GPS to guide many of his cross-continent and exploratory biking expeditions. He used a GPS unit during his attempt to cycle the length of Africa and during this annual treks to Mayan ruins for his interactive online education adventure.

. **Tourist-friendly GPS information systems**	4	**A** portable, laptop GPS-based tour guide is under development in Crete to help guide travelers through the winding streets of Crete, which welcomes **over** 1 million tourists a year.
Personal sport recreational use	7	GPS-based systems from are integrated with consumer devices for a variety of uses, such as hiking and fishfinding.
. **Avalanche rescue of hikers and skiers**	2	In Iceland, GPS-equipped snowmobiles **are** used in search and rescue operations. GPS allows emergency personnel to conduct rescues in bad weather and precisely guide medical care to victim locations.

APPLICATION: INFRASTRUCTURE DEVELOPMENT AND MANAGEMENT	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
. **GPS** aids water utilities in England and Wales	**5**	Six GPS receivers were used in the development of a newly privatized water district company, a consortium of ten water **utility** companies **that** merged when the old water utilities in England and Wales turned their responsibilities **over** to **the** private sector. This company serves **7.4** million customers with water, and 11.6 million customers with sewage services. GPS is used in the safe operation and monitoring of reservoirs operated by the district.
· **GPS** provides best accuracy for system-nidi utility inventory	4	**A** North Carolina utility outfitted mountain bikes with GPS mapping systems to approach and register 80,000 telephone poles and 60,000 other service features.
. **GPS** surveys one of the largest reservoirs **io** Europe	**4, 5**	The Departmento de Informacao Geografica, the survey and geodesy arm of HIDRORUMO, **an** engineering company of the Electricity of Portugal Group uses GPS to survey the border of the Alqueva dam, one of the largest artificial reservoirs in Europe. The survey also allowed engineers to **mark** the contour line defining the future submerged area, and to materialize and survey points defining this full storage level of the reservoir.
Restoring eroded hcachfroots	**5**	Surveys were launched by Auckland City Council in New Zealand to establish existing beach levels and to ensure correct sand replacement.
GPS for Quality **Assurance/Control** in **soli** waste landfills	**5**	GPS receivers are used at the Amarillo Municipal Solid Waste Landfill (Amarillo, Texas) to ensure permitted compliance required under an approved "Soil and Liner Quality Control Plan" **granted** by the Texas Natural Resources Conservation Commission. This plan guides the use of the landfill facility, which processes approximately 500 tons of waste per day of residential and nonhazardous industrial solid waste.

. **Reducing costs on expensive ground surveys in swamps, marshes and rainforests**	4	An oil and gas survey was conducted in Equatorial West Africa with two and a half times **greater** accuracy using GPS. Precision **siting** for environmental preservation is another capability.
· **Improved mapping and services on Native American lands**	4	Researchers in New Mexico **are** using GPS to map pueblos in New Mexico and other properties and facilities to improve not only tribal lands and services by law enforcement, **fire,** and rescue personnel
. **Surveying structures for seismic tolerance**	5	Coupled with **a** camera shutter situated on an airplane, GPS equipment revolutionized photogrammetry by performing a static survey in two days following the Loma Prieta earthquake.
. **Development of geodetic survey networks**	4	Engineers and surveyors in Greece, Russia, China, Puerto Rico, Brazil and Guam use GPS to build accurate survey networks to support development and growth.
. **GPS savings for the Cable TV industry**	4	Precise distance measurements of GPS reduced time to gather data for Cable TV runs in Colorado Springs
. **Providing subsidence measurements**	5	GPS receivers provide continual subsidence rate measurements to engineers on drilling platforms in the North Sea Ekofisk oilfield in Norway.
. **GPS used to develop water resources**	5	Engineers working for the Las Vegas Valley Water District are using GPS receivers to develop new wafer resources for the community of Jean, Nevada, located 30 miles south of central Las Vegas.

. **Precision surveying to map natersheds**	*5*	Using GPS, surveyors performed a survey of **the** area from Heppner, Oregon to the Columbia River, **45** miles away. This survey was done with GPS because U.S. A m y Corps of Engineers only had funding for 18 miles of survey from the dam. **As** a result, the entire survey, with a higher level of accuracy, was done at less than half the price of **a** conventional survey.
. **Monitoring subsidence at seaports**	*5*	Precision GPS is used to monitor subsidence at the Port of Long Beach, as well as to establish a network that could be used to replace some or **all** of **the** semi-annual precise leveling with GPS surveying.
Fast, inexpensive infrastructure development in underdeveloped countries	*6*	In China, GPS is playing an important role in the country's economic development. Using GPS, surveyors are able to quickly and accurately map large uncharted land masses and sea beds for natural resource harvesting, transportation infrastructure development and economically significant products.

APPLICATION: WEATHER FORECASTING AND OTHER SERVICES	RECEIVER TYPE	DESCRIPTIVE EXAMPLE
Measuring water vapor for wcather forecasting and climate rcsearcb	5	The National Oceanic and Atmospheric Administration (NOAA) successfully investigated the use of measuring atmospheric water using GPS data as a rcliable, continuous and low-cost measurement under any weather conditions. In this application. the highly accurate location information is disregarded. Instead, scientists study the time delay of GPS signals as they travel through the atmosphere.
. Measuring air-surface exchange for weather forecasting and climate rcsearcb	5	The National Oceanic and Atmospheric Administration developed low-cost airborne lechniques using GPS to measure air-surface exchange. Researchers investigating storms and other weather patterns can use the airborne measurements of wind, temperature, etc. Scientists studying pollution transport near shorelines and in complex terrain will also benefit from measuring turbulence and wind structures.
Mapping the wreckage of aircraft accidents	1	Within hours of the crash of TWA Flight 800, dozens of watercraft were on the site to provide search and rescue services. A NOAA vessel equipped with precision GPS technology was used to map the site and recover evidence to solve the mystery behind the crash.
· Accurate maps of postal codes	I	To increase efficiency of postal deliveries, the Postal Service teamed with the Census Bureau and the U.S. Geological Survey to map streets in mixed rural and urban areas, taking half the time using GPS.

THE WALL STREET JOURNAL. ONLINE

March 24,2003

PORTALS
By LEE GOMES

Military's Use of GPS Is at Core of Its Might

Talk about dual use. One minute, a satellite is helping a North American golfer choose what club to use in his approach to the green. A few hours later, it is dead-aiming some cruise missiles into the marble palaces of Baghdad.

The 27 orbiting birds of the Global Positioning System are perhaps the smartest of all the smart arrows in the U.S. military's quiver. They are helping make possible the precision-guided devastation of the war so far. American fighters should enjoy GPS while they can; these sorts of technological advantages never last very long.

ABOUT LEE GOMES

Lee Gomes, who writes the Portals column on Monday and the Portals Exchange on Friday, has been covering various topics. technical and otherwise, for The Wall Street Journal since 1996. He is a graduate of the University of Hawaii and the Columbia University Graduate School of Journalism, and lives in San Francisco.

NOTE TO READERS

Lee Gomes's Boomtown columns are available here[4].

The GPS network was first conceived in the late 1960s and became fully operational in 1995. Since then, it has found its way into every fabric of both military and civilian life. **Along** with the Internet, GPS is one of the Defense Department's greatest dual-use technology hits.

Civilian GPS networks were initially the province of hikers and boaters, and GPS receivers were once the size of a shoebox. No more. **All** new cellphones will be required by law to have GPS-like technology built into them, and **Motorola** just introduced a GPS receiver the size of a dime.

Pretty soon, GPS will be everywhere, and you won't be able to go anywhere without knowing exactly where you are, to an accuracy of a few feet. For GPS-enabled golf, for example, you snap a GPS receiver into your PDA, then see your precise distance to the hole. How did golfers ever manage to play without it?

The GPS satellites, flying in crisscrossing paths 11,000 miles high, make two orbits every day. The whole system is tracked carefully from a few desks at Schriever Air Force Base in Colorado. Periodically, technicians send commands nudging the birds back into their proper orbits. Because the satellites have a life span of about seven years, new ones are constantly being sent up. Of the 27 now in orbit, three are considered backups.

In its early days, GPS had a so-called selective-availability feature that gave a more-accurate signal to military users. That feature has since been turned off, and while the Pentagon reserves the right to turn it back on, it's doubtful it ever will. Civilian GPS products that would suddenly become less accurate are everywhere, including in the military.

IRAQ CONFLICT

. For continuing coverage. see War in Iraq.'

The Pentagon likes GPS because it overcomes many limitations of the smart technologies used in the first **Gulf** War. While laser-guided bombs, for instance, are utterly

lost in smoke or clouds, neither poses the slightest challenge to GPS -- a fact the Iraqi military doesn't seem to appreciate as it sets big fires around Baghdad.

For all its wonders, though, GPS is far from perfect, at least for the Pentagon. The main problem is that the transmissions from GPS satellites are extremely weak. That was by design, so that the signals wouldn't interfere with other forms of broadcast. But the result is that GPS is easy to jam. You can even find plans for GPS jammers on the Internet.

A large, powerful GPS jamming station is of limited military use, however, because its transmissions give away its location. Still, Pentagon planners were worried about cheap, low-powered jammers scattered on Baghdad rooftops.

Did they find any? No one is saying.

Even without GPS, most or all of the U.S.'s smart weapons can fly because they contain alternative, if less accurate, navigational technologies. The Pentagon already is planning a $15 billion replacement of the system, though this network, dubbed GPS III won't be operational for another decade.

The ability to wage war with a minimum of civilian casualties seems like a great advance. But there may be. What if the use of GPS-based weapons spreads around the globe and makes war more frequent by making it less bloody, and therefore less politically risky for the civilians who decide when to launch a conflict?

No new technologies stay in one country forever; think of radar or the atomic bomb. It is useless to talk about "containing" something like GPS. The same is true for many of the other technologies being used by our smart military. Scratch a lot of military systems, and you find something underneath that looks a lot like a PC.

Already, GPS-enabled products are beginning to turn up in the global arms trade. In itself, that's no cause for great alarm. GPS only buys you navigation; you still have to worry about delivering the weapon and about avoiding the enemy's defenses

As the war continues, and grows more complicated and more harrowing, it's hard to say what role technologies like GPS will play in the final public perception of the conflict. Friday and Saturday, after the first nights of shock and awe, it looked like technology would make this a relatively quick and clean conflict, at least for Americans. By Sunday, the ugly images of battles, war dead and P.O.W.s served as a reminder that there are some things about wars that even GPS satellites will never change.

• Send your comments to lee.gomes@wsj.com[2], and check back on Friday for some selected letters at WSJ.com/Portals[3].

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*Updated **March** 24, 2003*

GPS satellite network goes to war

By Alan Boyle. MSNBC

The Global Positioning System started out decades ago as a satellite-based network for military location and navigation, but in the past few years it's spawned a host of civilian applications -- including high-tech direction-finders for automobiles and hikers. Now GPS is going to war again, raising questions about what happens on the homefront.

THE U.S. MILITARY is using GPS as the backbone for its battlefield communication system, as well as **the** guidance system for a wide array of "smart bombs"-- including the "Mother of All Bombs".

Such satellite-based guidance systems aren't foolproof, as was demonstrated during the Afghan war, but they're considered far less vulnerable to the smoke and fog of war than the laser-guided munitions that played such a large role in the first Gulf War.

All this makes the GPS network, which relies on radio readings from a constellation of orbiting satellites, a powerful weapon -- and a potential target -- during any war in Iraq. Iraqi forces may well try jamming GPS signals. or "spoofing" GPS transmissions to lead the invading forces astray. Saddam Hussein's troops also may be using GPS. or Russia's less capable Glonass satellite navigation system, for their own purposes.

On Slashdot and other forums, GPS users have been debating whether the U.S. military will be "dumbing down" the satellite readings for civilians, as it once did. Until three years ago, civilian GPS readings were accurate only to a resolution of a football field or so -- and that's not good enough for today's high-precision applications.

"Why screw with good people who vote, like me, by screwing with my toys here at home?" one journalist complained Wednesday on an e-mail discussion list.

Richard Langley, a University of New Brunswick geodesy professor who has studied GPS for 20 years, told MSNBC.com that civilian users probably have nothing to worry about.

Back in 2000, the U.S. military said it wouldn't go back to the bad old days of "intentional degradation" of GPS signals. Instead, it would use more targeted tactics, including selective signal-jamming in the theater of military operations.

"People outside the theater can expect to use GPS as they have. ... Of course, national security overrides any statement that may have been made," Langley said.

In a detailed set of "frequently asked questions," Langley explains why the U.S. military still has the upper hand in GPS technology. Here are some of the strategies that could come into play during the conflict in Iraq:

Spoofing: The GPS network actually transmits two sets of locator signals: the civilian code, and an encrypted military code.

The Iraqis could conceivably send out "spoof" GPS-like signals that would fool the civilian-grade technology, but they wouldn't have the "P code" used by the military.

"Ground troops have been cautioned not to rely on civilian GPS receivers because they can be spoofed. You wouldn't want to rely on the coordinates from a spoofed receiver to coordinate live fire," Langley said.

If the Iraqis are using GPS or Glonass themselves. Langley said U.S. troops could turn the tables on them

"It's not out of the realm of possibility that the U.S. could spoof them, and then the coordinates given by the (Iraqi) receivers would be in error," he said.

Jamming: For a long time, low-cost GPS jammers have been widely available, and Iraqis have reportedly purchased such devices. The "pizza dish" antennas used for satellite-TV reception can even be hacked to jam GPS signals.

The fact that there are two GPS frequencies makes it harder Io jam U.S. military equipment -- and the Iraqi jamming signal itself would quickly attract U.S. fire.

"When the bad guys are picking jobs, (they) don't want to pick 'GPS jammer.'" Lt. Col. John Carter, chief of space requirements at the Pentagon, told Air Force Print News.

Satellite-guided bombs could switch to inertial navigation as a backup, Langley said

"If they lose the GPS signal for any reason, jamming or otherwise, then they will resort to using the inertial navigation system alone," he said. "That would still give them good accuracy -- not quite as good as with GPS. but good enough to do the job."

The U.S. military could well conducl its own jamming operation against the Iraqis if necessary, blocking out the civilian frequency while leaving the military frequency clear. However, that could cause problems for some of the Pentagon's older GPS receivers, which depend on the civilian frequency to get an initial fix.

"The U.S. military may or may not decide to jam in Iraq," Langley wrote in his FAQ. "The decision to do so will depend on whether or not they think the Iraqis are using GPS (would you really want to rely on your enemy's system?) and whether or not its use would compromise their own operations."

Anti-jamming: The U.S. military is also working to make it GPS equipment more jam-proof, on the ground and in the air. Antenna systems, for example, can sense the direction from which the jamming signals is coming, then cancel out that signal.

"Just because you're transmitting the jamming signal, there's no guarantee that the jamming is going to be successful," Langley said.

Future GPS satellites will come with a more flexible transmission system that can be adjusted from the ground to overcome jamming, the Air Force said.